Mangifera indica L. Mango

Anacardiaceae Cashew family

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Mangifera indica L., commonly known as mango, is a medium-sized to large evergreen tree that typically grows to a height of 25 m with a very dense, rounded crown of large, dark-green leaves and a stout trunk with thick, rough bark (fig. 1). Native to tropical Asia, mango has been planted throughout the semiarid to subhumid tropics and subtropics and has become naturalized in many parts of the introduced range. It is one of the most popular fruit trees throughout its range, and its wood is widely used for furniture, carpentry, construction, and other purposes.

HABITAT

Native and Introduced Ranges

Although its precise center of origin is not known, mango is probably indigenous to the lower montane forests of eastern India, Bhutan, Bangladesh, and Myanmar between latitudes 16° and 28° N. (*3, 6, 35*) (fig. 2.). Some authors believe its native range may also include the hill forests of central and southwestern India, Thailand, Laos, Vietnam, Kampuchea, and peninsular Malaysia (*3, 53*).

Mango has been cultivated for 4,000 years in south and Southeast Asia and is frequently referred to in the early Sanskrit literature of India (*3*). During the fifth and fourth centuries B.C., mango was carried by Buddhist monks from India to the Malayan peninsula and other parts of Southeast and east Asia (*35*). During the 10th century A.D., it was transported by the Persians from its native India to the Middle East. During the 16th century, it was introduced to east and west Africa from Goa (India) by Portuguese traders (*34*). Mango was introduced to Mexico and Brazil before the end of the 17th century and to the West Indies (from Brazil) during the 18th century (*3*). Since that time, mango has been so extensively planted and naturalized that its distribution may be considered pantropical. It has been successfully planted in a number of subtropical regions, including the shores of the Persian Gulf and the Mediterranean, the Canary Islands, South Africa, southern Brazil, southern California, and Florida (*3*).

Climate

The native range of mango is characterized by an annual rainfall of between 1500 and 2600 mm, with a dry season of 4 to 5 months between November and March (*7, 34*). Throughout its tropical and subtropical range, it grows well on sites receiving an annual rainfall in excess of 750 mm. Excessive humidity is detrimental to fruit production, however, and the highest yields are realized on sites receiving between 750 and 1300 mm rainfall with a well-defined dry season during the period of flowering (*3*). In Puerto Rico, mango has naturalized on sites where the annual rainfall varies from 1000 to 2600 mm (*17*).

In its native range, mean annual temperatures range from 24 to 27 °C, with mean minimum temperatures of 11 to 17 °C and mean maximum temperatures of 32 to 34 °C during the coldest and warmest months, respectively (*7*). Mango trees can tolerate light frosts (*53*).

Soils and Topography

In most parts of its native range, mango grows in natural forests at elevations from 300 to 900 m (*3*). It has been successfully grown from sea level to a 1,500-m elevation (*48*), although it grows best below altitudes of 600 m (*36*). While it prefers deep, well-drained alluvial loams and sandy loams (*36, 53*), many parts of its native and introduced range are characterized by soils derived from gneiss and other crystalline and metamorphic parent materials (*3, 7*). Mango grows poorly on compact clays, calcareous soils, and soils with a rocky subsoil (*15*).

In Puerto Rico, mango has become naturalized throughout the Island on a wide variety of soils of medium fertility, including Alfisols, Entisols, Histosols, Inceptisols, Mollisols, and Ultisols, with the exception of the mangrove, dry limestone, and upper montane regions (*29*). Soil pH of the former sites range from 4.5 to 7.5, and include drought-prone, excessively drained soils; moist, well-drained soils; and poorly

Figure 1.—*Mango* (Mangifera indica) *in Puerto Rico.*

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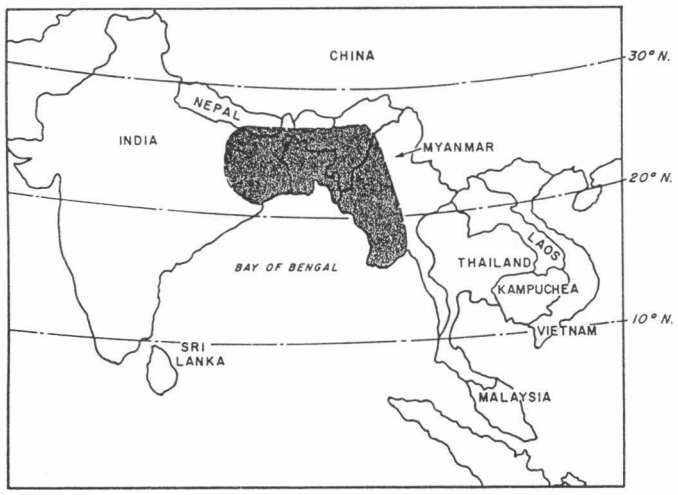

Figure 2.—*Shaded area represents approximate native range of mango* (Mangifera indica).

drained soils with anaerobic subsoils (*17*). It grows best, however, on well-drained loams with a high organic matter content (*34*).

Associated Forest Cover

In its native Indo-Burma range, mango grows in secondary moist deciduous forests in a codominant canopy position with *Anthocephalus cadamba* (Roxb.) Miq., *Alstonia scholaris* R. Br., *Dillenia pentagyna* Roxb., *Schleichera trijuga* Willd., *Terminalia tomentosa* W. & A., *Bursera serrata* Colebr., *Melia composita* Willd., and *Bridelia retusa* Spreng. (*7*). In West Bengal (India) it grows in association with *Butea monosperma* (L.) Taubert, *Madhuca latifolia*, *Pterocarpus macrocarpus* Kunz and *Shorea robusta* Gaertn. (*45*). In a 50-ha dipterocarp forest plot located in the Pasoh Forest Reserve of peninsular Malaysia, it grows in association with 820 other tree species (*41*).

In Puerto Rico and elsewhere in the West Indies, mango is common on abandoned farms and in secondary forests in the subtropical dry, moist, and wet forest life zones (sensu Holdridge, 22). In Antigua, it is associated with *Inga fagifolia* (L.) Willd., *Pisonia fragrans* Dum.-Cours., *Daphnopsis americana* (Mill.) J.R. Johnst. ssp. *caribaea*, and *Tabebuia heterophylla* (DC.) Britton (*4*). In central Honduras, it grows as a volunteer species in moist pine-oak forests and in riparian habitats at elevations between 600 and 900 m (*28*).

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Flowering in mango usually begins when trees are about 10 years old, although trees propagated vegetatively (by budding) may begin to flower during the first year and set fruit within 4 to 5 years. Flowering phenologies differ among varieties and with location. While a few varieties in India flower over a long period, with two or three flushes per year, most varieties blossom once a year (*34*). Flowering generally occurs from February to April in northern India, from January to March in southern India, from January to February in west Africa, and from November to July in Puerto Rico and elsewhere in the Caribbean (*29, 34, 53*). Flower production tends to be highly variable from year to year for many mango varieties (*3*).

The short-stalked, fragrant flowers have fine hairs and are partly male and partly bisexual (polygamous) and form large terminal clusters (panicles) 15 to 20 cm long with reddish, hairy branches with up to 6,000 flowers (*29*) (fig. 3). Individual flowers consist of a yellow-green, deeply lobed calyx 1.5 mm long; five spreading petals 3 to 4 mm long, ranging in color from red to pink to white; five stamens; and, on bisexual flowers, a pistil with a one-celled ovary and a slender lateral style (*29*). Insects, particularly species of the orders Diptera, Hymenoptera, Lepidoptera, and Coleoptera, are the primary pollinating agents (*34*).

The single-seeded, elliptical, aromatic fruits, or drupes, mature 2 to 4 months after flowering, depending on variety and locality (*34*). The wild fruits are about 3.5 to 10 cm long, while those of most cultivated varieties are considerably larger (*34, 53*), usually 8 to 20 cm long and 6 to 12 cm broad, slightly flattened and narrowed toward the apex.

Seed Production and Dissemination.—The seed, enclosed in a fibrous putamen and set in a thick, juicy, orange pulp, is flattened and weighs approximately 25 g (*29*), or about 13 percent of the total fruit weight (*36*). Fruit bats and other frugiverous mammals are the primary seed dispersal agents in the native range. Elsewhere, seeds are dispersed by livestock and humans. Seeds for planting should be collected from fully mature, naturally dropped fruits, depulped, and air-dried in a cool place.

Seedling Development.—For nursery production, the pulp should be removed from the fibrous putamen prior to sowing in loose soil. As mango seeds have a limited period of

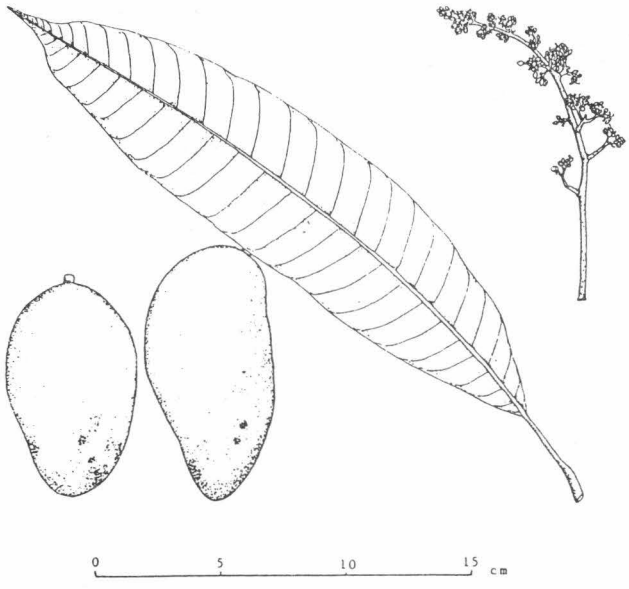

Figure 3.—*Foliage and fruit of mango* (Mangifera indica) (*28*).

viability, ranging from 80 to 100 days when stored under cool conditions (*36*), they should be sown as soon as possible after ripening. Germination in mango is hypogenous and occurs approximately 1 month after sowing (*15, 53*). The stout radicle emerges from the end of the seed, and the broad fleshy cotyledonary petioles elongate, enabling the young shoot to emerge. The cotyledons remain within the fibrous putamen on or below the ground (*53*). In some polyembryonic varieties, between two and eight shoots are produced from a single seed; in the nursery, these should be thinned soon after germination to allow healthy development of a single shoot. The seedling produces a moderately long and stout tapering primary root with numerous moderately thick lateral roots distributed along its length (*53*). Seedlings require partial shade for optimal early development (*15*).

The early growth of the seedling is rapid. Under subtropical conditions in northern India, seedlings grow 20 to 30 cm in height shortly after germination and 30 to 45 cm in 4 months, 75 to 150 cm in 16 months, and 1.5 to 2.7 m in 28 months after sowing (*53*). Nursery-raised seedlings should be outplanted when seedlings are approximately 45 to 60 cm tall with stem diameters between 1. 2 and 1. 5 cm, or before the taproot has developed to any great extent (*15, 50, 53*). Plantations are commonly established using potted seedlings at the beginning of the rainy season. Planting holes measuring 60 by 60 by 60 cm are commonly prepared and filled with loose soil enriched with compost or manure to ensure vigorous root development (*36*). Shading of seedlings during the establishment phase is recommended (*15*).

The natural regeneration of mango is good, particularly under light shade. Seeds germinate readily beneath parent trees and when protected from full sunlight, as in the understory of secondary forests (*53*). In Puerto Rico, natural regeneration is relatively abundant along trails and roads in secondary forest stands except on wetter sites[1], where regeneration is sparse, possibly due to excessive humidity and low fruit production or to high seedling mortality.

Vegetative Reproduction.—Mango is commonly propagated vegetatively by various budding and grafting techniques (*34*). Budding is performed using seedlings with stems 0.7 cm or greater in diameter when the terminal bud is just starting to expand. Grafting is practiced on 10- to 12-month-old seedlings or those with stem diameters of approximately 1.0 to 1.5 cm (*3*). Mango trees coppice well after cutting (*48*).

Sapling and Pole Stage to Maturity

Growth and Yield.—While vegetatively propagated mango trees may begin to produce fruit as early as 4 to 5 years of age, their full productive capacity is reached between 20 and 40 years of age (*50*). Mature trees often yield 1,000 to 3,000 fruits per year.

Mature trees typically grow to heights of 25 m, occasionally taller, with clear boles up to 15 m and diameters at breast height (d.b.h.'s) between 0.6 and 2.0 m (*48, 53*). The largest mango measured in Puerto Rico was 37.3 m tall with a d.b.h. of 2.0 m.[2]

Mango was the ninth most important tree (in terms of total basal area of 173 species sampled) in an inventory of Puerto Rican secondary forests in 1980 (*5*). Slightly more than 40,000 m^2 of basal area, or an average of 0.35 m^2/ha (2.5 percent of the total), was estimated for mango in these secondary forests, most of it in the larger diameter classes.

Rooting Habit.—Mango has a deeply penetrating taproot and extensive lateral root system (*36*). Root system morphology varies greatly on soils with different profile textural sequences. Trees growing on sites with coarse- or medium-textured soils tend to form very deep taproots and lateral roots to a depth of at least 1.7 m, while those on sites with fine-textured soils tend to have a more shallow, more sparse, and less extensive taproot and lateral root development. On clay soils, lateral roots near the stem often protrude above the soil surface. While lateral roots may be more extensive in coarser than in lighter textured soils, the fine, feeding roots tend to be concentrated closer to the stem in the coarser soils (*1*).

Reaction to Competition.—Mango is moderately shade tolerant (*53*). Tree spacing in plantations depends on the variety: dwarf varieties can be planted at spacings from 6 by 6 m to 7.5 by 7.5 m, while spacings ranging from 9 by 9 m to 12 by 12 m, or even 15 by 15 m, may be necessary for some varieties (*36*). Denser plantings such as 6 by 6 m are sometimes used to improve early productivity and economic returns; upon canopy closure, such plantations should be thinned to a final spacing of 12 by 12 m (*36*). In Puerto Rico, commercial plantations are managed in hedged rows at close spacings. Intercropping with herbaceous legumes, vegetables, papaya, pineapples, and other food crops is commonly practiced during the first 3 to 4 years after plantation establishment, or until the canopy closes (*34, 36*). During the early stages of development, tree growth may be impeded by competition from grasses, cover crops, and other herbaceous vegetation. Regular weeding around stems is therefore recommended during the first few years of plantation growth (*36*)

Damaging Agents.—A number of insect species have been reported to be serious pests of mango, particularly those belonging to the orders Diptera and Homoptera. These include several fruit flies (Diptera: Trypetidae), notably the Mediterranean fruit fly, *Ceratitis capitata* Wied. (in Hawaii); the Queensland fruit fly, *Dacus tryoni*; the mango fruit fly, *D. ferrugineus* Fabr. in India; *Anastrepha fraterculus* Weid. (Dipera: Tephritidae) in the West Indies; and *A. mombinpraeoptans Sein* in Puerto Rico (*3, 31, 34*). Fruit damage by the larvae of *A. fraterculus* has been reported in Colombia (*57*). Other insects causing moderate or serious damage to mango in Puerto Rico include the branch and leaf boring larvae of *Chlorida festiva* L. (Coleoptera: Cerambycidae); *Aulacaspis tubercularis* Newstead (Homoptera: Diaspididae); the ant *Myrmelachista ramulorum* Wheeler (Hymenoptera: Formicidae), which bores in twigs and larger branches; and

[1]Alemañy, Salvador. 1992. Personal communication with the author. On file with: International Institute of Tropical Forestry, U.S. Department of Agriculture, Forest Service, Río Piedras, PR 00928-2500.

[2]Francis, John. K.; Alemañy, Salvador. [n.d.] Champion trees of Puerto Rico. Unpublished manuscript on file with International Institute of Tropical Forestry, U.S. Department of Agriculture, Forest Service, Río Piedras, PR 00928-2500.

the thrip *Selenothrips rubrocinctus* (Giard) (Thysanoptera: Thripidae) (*18, 31*). Nematode damage by *Rotylenchulus reniformis* and *Hemicriconemoides mangiferae* has been reported in Florida (*32*).

In India, the mango hoppers, *Idiocerus clypealis* Leth. and *I. niveosparsus* Leth., and other idiocerine leafhoppers (Homoptera: Cicadellidae); the mango flea weevil, *Rhynchaenus mangiferae* Marshal (Coleoptera: Curculionidae); and the mango weevil, *Cryptorhynchus mangiferae*; are important pests (*3, 25, 34, 43, 55*). The psyllid shootgall, *Apsylla cistellata*, causes moderate damage in some mango varieties in northern India (*26*). The stone weevils, *Sternochetus mangiferae* Fabr. and *S. gravis* Fabr., cause considerable damage to fruits in southern India and Hawaii (*2, 34*). Numerous species of nematodes have been reported to infest mango plantations in India (*38*).

A large bark-boring beetle, *Plocaederus ruficornis*, is a serious pest in the Philippines (*3*). Inflorescence malformation caused by infestation by the bud mite *Aceria mangiferae* has been reported for some mango varieties in Egypt (*56*). The giant mango mealybug, *Drosicha stebbingi*, feeds on succulent parts of the tree and is an important pest in some regions (*36*). Sixteen species of phytoparasitic nematodes, including *Pratylenchus* spp., *Helicotylenchus* spp., *Xiphinema brevicolle*, and *Hemicriconemoides mangiferae*, were reported to cause severe damage in old plantations in South Africa (*33*).

Mango is susceptible to flower-blight, or anthracnose, caused by *Colletotrichum gleosporioides* Penz.—an imperfect-stage name of *Glomerella cingulata* (Ston.) Spauld. & Schrenk—a cosmopolitan fungal disease that occurs most commonly during moist periods (*3, 21, 36*). Black blight or sooty mold, caused by *Capnodium mangiferum* Cook & Brown; *C. ramosum* Cooke; and *Meliola mangiferae* Earlle, which grow on the "honey dew" secretions of leaf hoppers or scale insects, is a common problem in India and elsewhere (*34*). Mango scab, or spot-anthracnose, caused by the fungus *Elsinoë mangiferae* Bitanc. & Jenkins, sometimes seriously damages leaves, twigs, flowers, and fruits (*36*). The powdery mildew, *Oidium mangiferae* Berthet; pink disease, *Corticum salmonicolor* Berk. & Br.; slack stem, *Rhinocladium corticolum* Mass.; and red rot, *Cephaleuros virescens* Kunz., are of minor importance in India (*20, 25, 34*). Fruit rot and stem canker caused by the bacteria *Erwinia carotovora* and *E. herbicola* are widespread in Venezuela, although some varieties are reportedly tolerant (*19*). A number of other diseases of mango have been reported in California, Florida (*21, 47, 54*), and Puerto Rico (*54*), although few, if any, of these cause serious, widespread damage.

Mango trees are sensitive to deficiencies in nitrogen, potassium, and some micronutrients (*21, 34*). Seedlings are susceptible to rodent damage, and young trees require protection against browsing by livestock (*49, 50*). While trees may suffer considerable damage in high winds, they generally produce new branches and foliage rapidly.

SPECIAL USES

Although the wood and other parts of the tree are often used, mango is grown principally for its fruits. Worldwide, an estimated 13.5 million tons of mangos are consumed annually (*50*). These are usually eaten raw as a dessert fruit, although they are sometimes cooked or used in iced drinks, sherberts, and other dessert dishes. Both green and ripe mango fruits are rich in carbohydrates, minerals, and vitamin C (*15, 34, 50*). In India, mangos are used in the manufacture of chutneys and preserves and are pickled in spices for use as a condiment (*50*). A tart powder called "amchur," made from the dried, ground pulp of the fruit, is used in Indian cooking. The ground seeds are sometimes used for flour (*34, 46*). The flowers and very young leaves are eaten in some Southeast Asian locales (*34*). In Sulawesi (Indonesia), the fruits are sometimes used to make vinegar as well as a type of brandy (*34*). The fruits are readily eaten by livestock, and the leaves and seeds are sometimes used as fodder in mixtures with other forages (*39, 51*) for sheep and cows.

The leaves, dried flowers, unripe fruits, seeds, bark, and resinous gum are used medicinally for the treatment of a wide variety of diseases and ailments in India (*8, 9, 10, 24, 27, 44*), the Philippines (*6*), west Africa (*50*), and Central America (*12*). These are most commonly used in the treatment of skin diseases and wounds, digestive disorders, and respiratory ailments. Leaf extracts reportedly exhibit broad spectrum antibacterial and antifungal activity (*23*). The powdered flowers are used as a mosquito repellent (*42*).

The bark and leaves contain a yellow dye that gives a light-yellow shade to cotton, silk, and wool (*34*). The powdered bark is also used in a mixture with other ingredients for glazing pottery (*11*). The dried immature fruits are used as a mordant (fixative) for vegetable dyes such as safflower (*11*). A perfume known as "amb attar" is distilled from the flowers (*11*). The flowers and leaves are used in Hindu religious ceremonies (*46*).

The sapwood is cream colored or light brown, and the heartwood is pale yellow or brown and often mottled or irregularly lined. The wood is moderately hard, lustrous, medium textured, moderately heavy (specific gravity: 0.62), and strong, with a straight to wavy grain, many large pores, and growth rings (*30*). The wood seasons at a moderate rate with only minor degrade. The wood works easily but with only fair results and is moderately resistant to dry-wood termites (*30*). In Puerto Rico, the wood has been used only to a limited extent for chopping blocks and fuelwood (*29*). In south Asia it is used for underwater piles, boats, furniture, carpentry, flooring, construction, boxes and crates, carts, plows, and plywood (*11, 52*).

Mango is an excellent hardy shade tree and is widely planted in urban and rural areas as an amenity. It is a very popular component of home gardens throughout its tropical American range (*37, 40*). In Costa Rica, mango is cultivated in agroforestry systems with coffee, (*Coffea arabica* L.); *Citrus* spp.; *Musa* spp.; *Inga* spp.; *Erythrina* spp.; and timber species such as *Cedrela odorata* L. (*14*). The tree is an important forage plant for honeybees, which feed on the nectar secreted in abundance from the inflorescences (*13*).

GENETICS

Of the hundreds of named, cultivated varieties of mango, most belong to two distinct races, a monoembryonic race that includes several fairly well-defined groups or types from India and a polyembryonic race from the Philippines and Indo-

China (*3*). Within the latter Philippine race, several more or less distinct seedling types, notably Pahutan, Carabao, and Pico, include a large number of horticultural varieties. Mangos introduced to Mexico during the 17th century and still cultivated today were of the Philippine race. Several hundred horticultural varieties from India comprise a number of distinct groups known as the Bombay, Hangra, and Malda types, all of which are monoembryonic. Only a very limited number of these, such as the Alfonso, Mulgoba, and Dusseri varieties have become well known and generally recognized. Varieties of both the Philippine and Indian races have been introduced to the West Indies and southern Florida, the most common known as Mulgoba, Haden, Pairi, Amini, Cambodiana, Bennet, and Sandersha (*3*).

There is considerable variation in susceptibility to pests and diseases, fruit size, shape, color, and texture among cultivated mango varieties. Some varieties are no larger than a plum, while others may weigh as much as 2 kg (*3*). The shape varies from round to long and slender, the most common varieties being reniform, obliquely heart shaped, oval, or elliptical. Fruit color may range from greenish yellow through various shades of yellow and orange to scarlet (*3*).

The genus *Mangifera* consists of more than 60 species, most of which are native to the Malay Peninsula, Sumatra, and elsewhere in Southeast Asia (*35, 36*). Other species bearing edible fruit include *M. altissima, M. caesia* Jack, *M. cochinensis, M. foetida* Lour., *M. griffithii* Hk. f., *M. kemanga, M. lagenifera* Griff., *M. magnifica* Kochummen, *M. oblongifolia, M. odorata* Griff., *M. pentandra, M. quadrifida* Jack, *M. reba, M. sylvatica, M. verticillata* Rob., and *M. zeylandica* Hook. f. (*3, 34, 41*). None of these, however, are comparable in quality to mango (*36*). *Mangifera indica* is a diploid species with 40 chromosomes (*36*).

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